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# Skyshine from the SSC Interaction Regions*

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# Skyshine from the SSC Interaction Regions

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During the previous workship in this series (SSC Workshop on Environmental Radiation, October, 1985), concerns were expressed about neutron skyshine originating from the beam interactions. At that time relatively thinly shielded collision halls were being given serious consideration. I would like to review this topic briefly and present a rough calculation of the possible skyshine field based upon the more current designs for the collision halls expressed in the Conceptual Design Report (SSC-SR-2020). Furthermore I will also use calculations by A. Van Ginneken, et.al. in the recent report (Fermilab FN-447 (SSC-106), "Shielding Calculations for Multi-TeV Hadron Colliders"). The latter gives contours of dose equivalent per inelastic collision in a "wet" soil shield external to a collision hall.

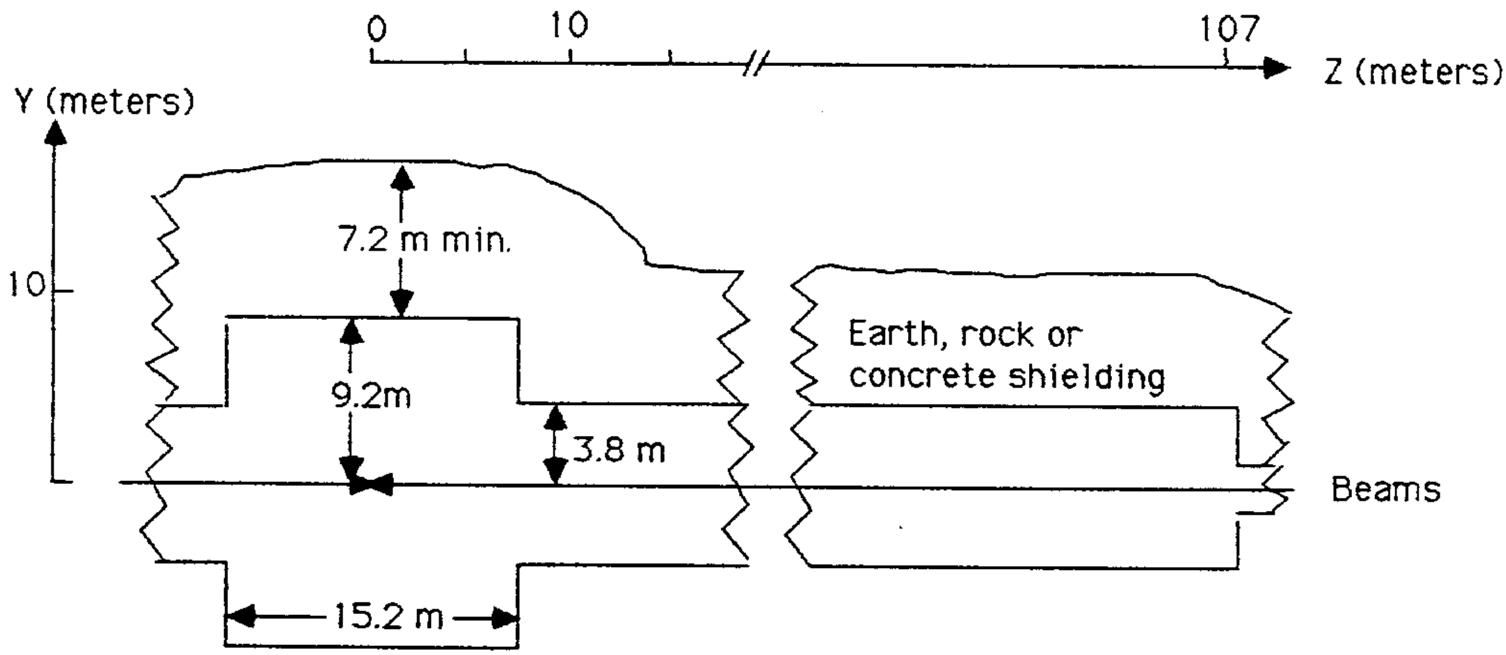
To go from these calculations to "skyshine" (i.e, radiation seen at ground level locations which do not view the source along a "line of sight") I will make use of a semiemperical formula which has successfully fit measurements made at Fermilab and elsewhere (Health Physics 48 (1985)175). In this method it is necessary to quantify the strength of the field by determining the integral of the dose equivalent (or total neutron emission) over the area of the source. The formula is as follows:

$$H(r) = [aQ/(4\pi r^2)][1-e^{-r/\mu}]e^{-r/\lambda}$$

Here, r is the radial distance from the (presumably) isotropic source in meters, a and $\mu$ have been determined to have the respective values of 2.8 and 56 m. $\lambda$ is dependent upon details of the energy spectrum of the emergent neutrons but could be expected to range between 250 and 1200 m. The lower end of this range would be generally expected for a reasonably thick concrete or soil shield. The parameter Q denotes the source strength and, for purposes of discussion here, will be in units of mrem-$m^2$ per collision, or per unit time. H(r) is the dose equivalent (or neutron fluence) at r and must be dimensionally consistent with $Q/r^2$. An isotropic field is implied here, and is the usualy condition found in measurements.

The Conceptual Design Report describes two possible types of collision hall geometries. Consulting Van Ginneken's calculations of dose equivalent rates, it is obvious that "Type B" (the long, "skinny" one) is the most troublesome, especially if the extended large diameter tunnel for the forward/backward "arms" is shielded no more than is the central region. The figure below is a vertical cross section in the plane of the beam showing my interpretation of its specified shielding.

Vertical, Longitudinal Section
in Beam Plane ("Type B Collision Hall")



The next figure is a CASIM coutour plot calculated by Van Ginneken for such a collision hall geometry of somewhat larger dimensions. It should be pointed out that using this calculation is an exercise in extreme conservatism, there being no allowance made for the self-shielding of the massive detector almost certain to reside in such a hall. However, it seems conceivable that high luminosities could be produced in such an empty hall in order to prevent disruption of accelerator operations during servicing of the resident detector.

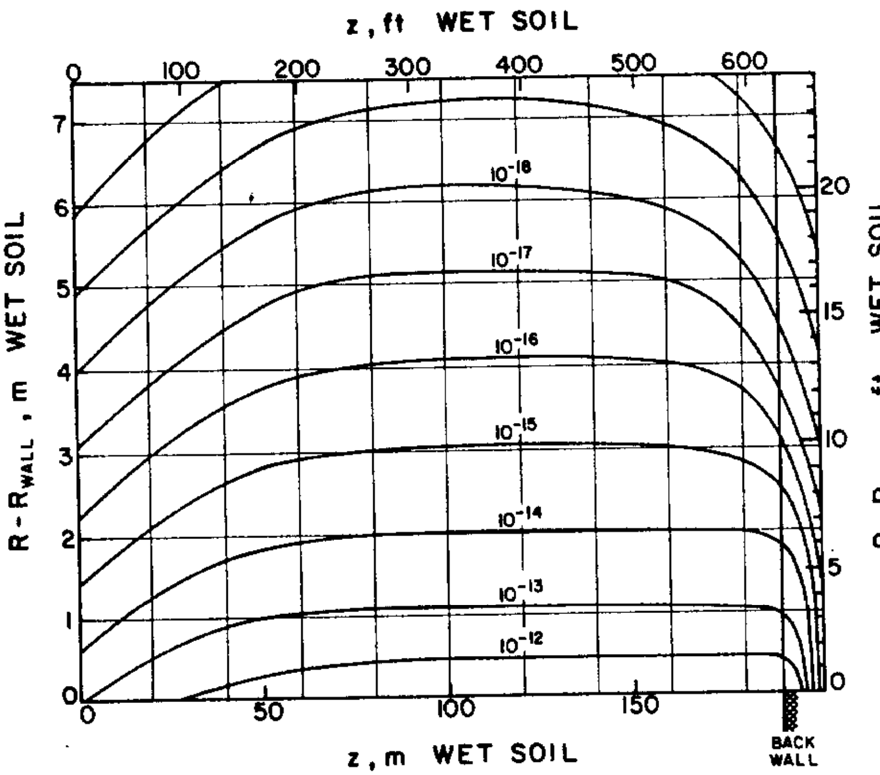
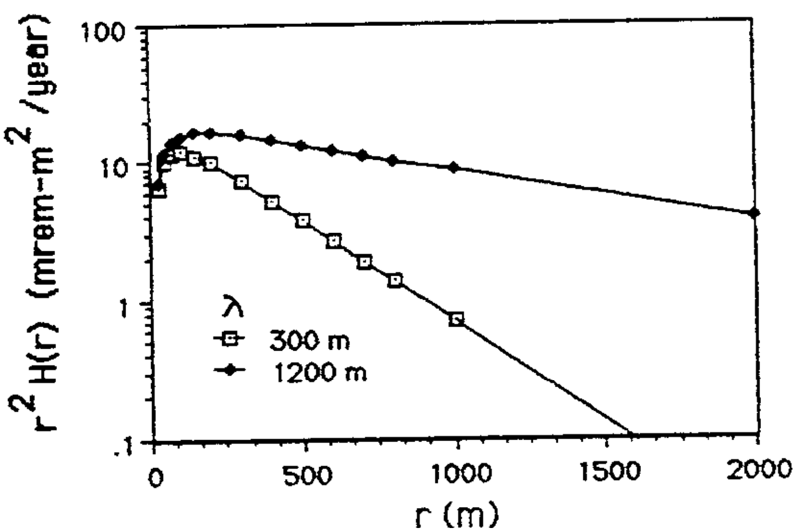



Fig. 144 Contours of equal dose equivalent (in rem/inelastic collision) in soil side wall of collision hall, due to hadrons from colliding beams of 20 TeV each. A 1 mm thick beampipe is present. Some contours may be omitted for clarity or due to statistical uncertainty.

It is obvious from the above curves that the 7.2 meter earth/rock shields postulated to be surrounding the hall will provide exceedingly low hadron dose equivalent rates to adjacent external areas. The maximum in the dose equivalent exterior to the "Type B" style collision hall is achieved some 100 m downstream of the vertex. Averaging these results over the region $0 < Z < 120$ meters (making a "line source" correction for the smaller enclosure dimensions) I obtain a value of $9.0 \times 10^{-20}$ rem/inelastic collision. (Contributions from locations at larger Z will be minimal due to the much greater shielding present over the normal accelerator tunnel sections.) The total area of this source is just about 1000 $m^2$. The maximum luminosity is predicted to be $10^{33}$ $cm^{-2}s^{-1}$. Taking the standard value of 90 mb for the inelastic cross section, this results in an interaction rate of $9 \times 10^7 s^{-1}$ or $\approx 10^{15}$ $y^{-1}$ (assuming 3000 hours of operation annually). Of course, in such an empty hall, the luminosity is likely to be very much lower to conserve beam for useful interactions elsewhere. The value of Q under these rather extreme assumptions is about 90 mrem-$m^2y^{-1}$. It is thus straight-forward to plot the skyshine equation and this has been done below for two rather extreme values of $\lambda$:



Here, the ordinate is selected to be $r^2H(r)$ in order to remove the very rapid inverse square law dependence. It is very clear that even very close, say at r = 25 m, the annual dose equivalent due to skyshine from such a source is only about 11 μrem. This value, which is comparable to that due to cosmic ray shower neutrons, could rise by about 3 1/2 orders of magnitude if a thinly shielded structure, similar to that at the Fermilab B0 collision hall were built. Under the present design, skyshine from proton-proton collisions is not a major concern.